National Transportation Safety Board

Office of Railroad, Pipeline and Hazardous Materials

Washington, DC 20594

RRD22LR008 – BOSTON, MASSACHUSETTS

MECHANICAL

Factual Report

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A. ACCIDENT

Location: Boston, Massachusetts
Date: April 10, 2022
Time: 12:30 am EDT
Train: Massachusetts Bay Transportation Authority, Red Line Subway Train

B. MECHANICAL GROUP

Group Chair	Ruben Payan Electrical Engineer National Transportation Safety Board
Group Member	Arun Modh Public Utilities Engineer The Commonwealth of Massachusetts, Department of Public Utilities
Group Member	Stephens C. Hicks Chief Mechanical Officer - Rail Massachusetts Bay Transportation Authority

C. SUMMARY

On April 10, at about 12:30 am local time, an MBTA passenger was fatally injured after a train door closed on their upper arm/shoulder at the Red Line Broadway Station. Security footage obtained indicates that the passenger was pinched between the doors while attempting to exit the train as the door began to close. As a result, the passenger was unable to get free and was pulled down the platform onto the right of way.

D. DETAILS OF THE INVESTIGATION

1.0 MBTA Red Line Fleet – Technical Description

1.1 General Description

Red Line trains were owned and operated by the Massachusetts Bay Transportation Authority. The Red Line Type 1 railcar fleet was comprised of twenty-four 1500 series subway cars, numbered 1500 to 1523 and fifty 1600 series subway cars numbered 1600 to 1651. At the time of the accident, six 1600 cars were on a long-term hold. The active size of the Type 1 railcar fleet was 68 Cars.

The 1500 and 1600 series railcars were 1969-1970 era railcars built by the Pullman-Standard Car Manufacturing Company. Trains consisted of mated car pairs designated as the "A" car (even numbered) and "B" car (odd numbered). The cars measured 69.75 feet in length (over coupler faces), were 10.25 feet in width, and 12.6 feet in height (from top of rail). "A" cars weighed about 64,850 lbs. and "B" cars weighed about 63.700 lbs. The railcars were propelled by a third-rail, 600-volt direct current (nominal) electrical power. Each car used a 37.5-volt battery system that was charged from the third rail by a direct current converter. The railcars were capable of an average acceleration rate of 2.5 mph/second. The railcar carbody consisted of a passenger compartment, and a train operator compartment. MBTA did not equip this series of railcars with event recorders.

On the exterior, the railcar ends were equipped with headlights, taillights, red marker lights, a front destination sign and an emergency bypass amber light was located on the right side underneath the destination sign. Both sides of the railcar were equipped with a door pilot light that displayed a red light when the passenger service doors were in the open position.

1.2 Train Operator Cab Description

The train operator compartment was located at the number 1 (cab) end of each railcar, adjacent to and connected with the passenger compartment. A cab fitted at the end of the car allowed the car to be operated (controlled) from either end, and allowed the multiple unit cars to operate bi-directionally (i.e., the car/train could be operated in a reverse direction without having to physically reverse the direction that the car was facing). The train operator compartment, which extended the width of the car, was a dedicated workspace for use by the train operator, and consisted of an operator's seat, a control panel (containing the car / train operating control features, and car / train condition instrumentation / monitoring equipment). A glass windshield was provided at the end of the car (that allowed the operator a view of the area in front of a car / train). A door was provided in the partition, which afforded access to the train operator's compartment from the passenger compartment. The train operator also had access to a cab end door which afforded access to the front exterior of the railcar (see Figure 1).

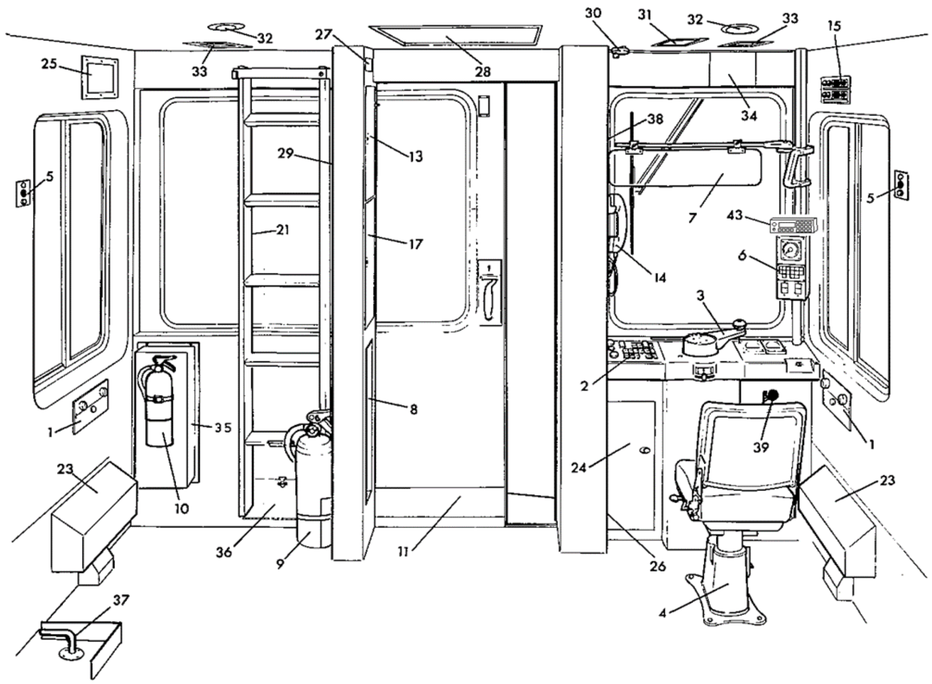

Figure 1. Train Operator Cab Diagram

Propulsion and braking inputs and adjustments were requested through the railcar Ciniston (master-controller handle). The master-controller handle also incorporated a deadman feature that required the train operator to hold the handle in a depressed position while the train was moving. Release of the handle while the train was in motion would initiate an emergency brake application.

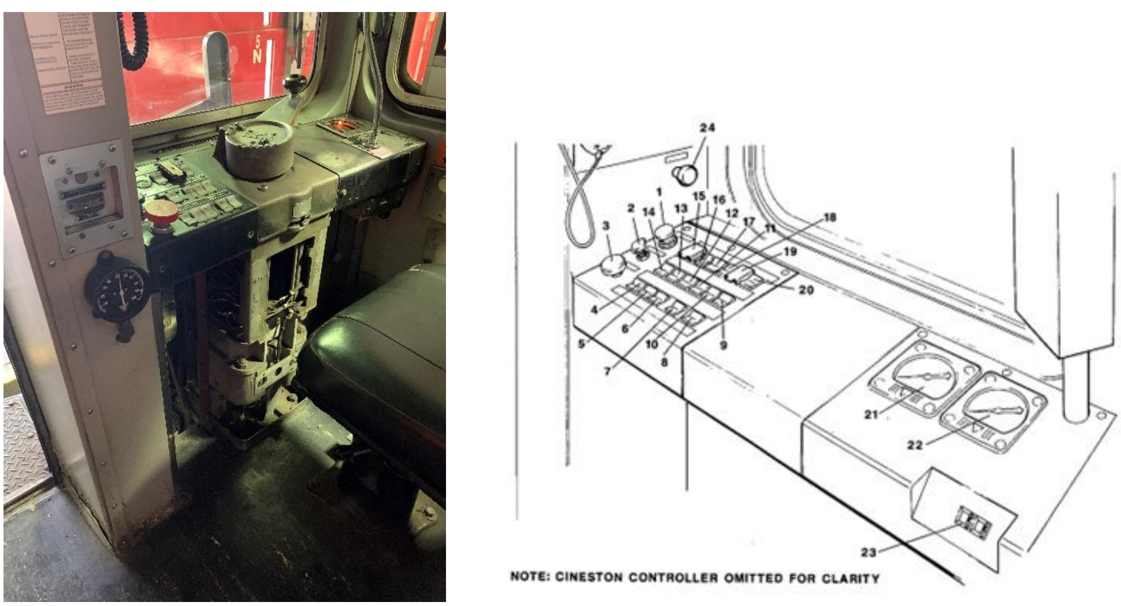

Figure 2. Car 1511 - Operator Control Console

Located adjacent to the master-controller handle on the train operator console were the horn, car lights, headlights and other railcar control buttons. An automatic door starting signal button was also located on the control console. When depressed by the train operator, the automatic door starting signal button would sound a buzzer if the passenger service doors on all railcars were in the closed position (see Figure 2).

1.3 Service Doors Operation

The Type 1 carbody was configured to service high-level platforms with the railcar floor level 49 inches above top of rail.[1] Passengers boarded, or disembarked, from the car through six, pneumatically-powered side doors, which were located along both sides of the railcar. The door-sets were double-leaf doors which were comprised of a single panel.

1.3.1 Door Open Command

To open the passenger doors, the door set-up switch was placed in the ON position. The train operator then placed the door operator switch to the Open position (applying 37 volts) to the door circuit. This activated the door open relay and if the train was at No Motion, below 3 mph, the No Motion relay was activated, closing the No Motion relay contacts which activated the Master Door relay. The Master Door relay contacts closed which applied 37 volts to the auxiliary lock solenoid and magnet valve which commanded the doors to open. The Master Door relay contact also placed 37 volts onto the trainline automatic door starting signal which activated the Master Door relay in each car in the train consist which in turn activated the auxiliary lock solenoid and the magnet valve opening the doors on the entire train consist.

1.3.2 Door Close Command

To close the doors, the train operator moved the door operator switch to the Close position which is sent the signal to ground. This deactivated the door open relay which opened the open door contacts and removed 37 volts from the master door relay. When the master door relay dropped out, the 37 volts were removed from the auxiliary lock solenoid and the magnet valve. When the power was removed, the doors began to close. The door close signal was sent trainline to the entire train consist which caused all doors to close.

1.3.3 Door Obstruction Detection

The door obstruction system was activated once the doors began to close. The sensitive edge caused the sensitive edge pressure switch to close which activated the

[1] The carbody is also not fitted with step-well staircases, which are typically utilized in street-operation service, and thus the railcar cannot accommodate passenger loading / unloading from low-level platforms.

door recycle relay. When the door recycle relay was activated the relay sent 37 volts to the magnet valve solenoid and the auxiliary lock solenoid. The activation of these solenoids caused the doors to open. When the doors were fully open the LS3 switch opened, removing 37volts from the magnet valve solenoid and the auxiliary lock solenoid and the doors would begin to close again.

1.3.4 Door Interlock

The door interlock circuit was controlled by the door interlock relay. The door interlock relay received power when the reverser switch on the master controller was in the forward or reverse position. The automatic door starting signal relay, door open relay, number 1 and number 2 were activated once the doors were closed. This signal was sent from each car to the lead car. The lead car then applied this signal to the door interlock relay which enabled propulsion. If any door was open, the door open relay would be in the open position and propulsion was disabled.

1.3.5 Service Door Pilot Lights

The door pilot lights would be energized (red marker light) when the passenger service doors would be in the open position. Following the door operator switch being moved to the close position, the LS1 switches on all doors would close, which indicated the door locking pawl had dropped and locked the door closed. The automatic door starting signal relay would be activated and the contacts would open. The open contacts would open the circuit that energized the door pilot lights and extinguish the lights to indicate all doors were closed and locked to the train operator.

2.0 Train Consist

The MBTA train consisted of three married-car pairs and was designated as Run #1034. All cars were operational in the train consist and coupled in the following sequence:

Position	Car Number
Lead	1511
2nd	1510
3rd	1614
4th	1615
5th	1757
Trail	1756

Table 1. Car numbers and positions for Run #1034

3.0 Accident Sequence

The MBTA subway train was departing the Broadway station platform after making a scheduled passenger station stop. The doors on the left side of the train were used by passengers and the train operator was operating from the right side of the lead car.

The fatally injured passenger was caught between the left-side, middle doors of the second car (Car 1510). Physical evidence was found starting along the side and undercarriage of the second car. Physical evidence was also found on a train trip-cock valve that was consistent with the train operator's postaccident interview statement of the train experiencing an unintended brake application shortly after departing the Broadway passenger station.

4.0 MBTA Fleet Preventative Maintenance Inspections

The MBTA preventive maintenance inspection (PMI) interval for the Red Line #1 and #2 fleets was 8,500 miles. The MBTA, policy was contained in Inspection Procedure EEQA52039.[2]

The 8,500-mile, vehicle inspection procedure contained the requirements to inspect and test:

- Truck Inspection
- Gear Units
- Traction Motors
- Propulsion
- Air System
- Auxiliary Electrics
- Couplers
- Car Interior
- Car Exterior
- Doors
- Equal Access Inspection
- HVAC

4.1 Service Doors PMI[3]

The door system maintenance inspections included visual inspections and functional checks of door operations and subsystems including the exterior door pilot lights and the automatic door starting signal button.

[2] Preventative Maintenance Inspection Policy, Red Line #1 and #2 Heavy Rail Car, issued 12/02/2020, Revision 0

[3] Appendix B: 8,500 mile vehicle inspection procedure, 10-Doors, 10.9-Obstruction Test – Top, Middle, Bottom. (page B-87)

The PMI required a door obstruction test. The door obstruction test required a visual inspection of the sensitive edge to identify any damages and an inspection of the gap between the sensitive edges with the doors closed and locked.

The door obstruction test also required a functional inspection to be performed. The functional test involved placing a 7/8-inch diameter dowel against and perpendicular to the edge of the adjacent closed door at 3 locations: 6 inches from top, center and 6 inches from the bottom of the door. Each door was required to recycle while the dowel was held in place.

4.2 Run #1034 - PMI Records

MBTA provided PMI records for the Run #1034 railcars involved in the accident. Table 2 lists the dates of the last PMI for each railcar.

Car Number	**Date of PMI**	**Mileage since last PMI (miles)**
1511	March 27, 2022	8,259
1510	March 27, 2022	8,259
1614	February 18, 2022	7,911
1615	February 18, 2022	7,917
1757	February 2, 2022	7,802
1756	February 2, 2022	7,802

Table 2. MBTA PMI Dates

As part of the Air System Reliability Program, MBTA overhauled the C-3-B Cineston on all 1500 and 1600 series cars. According to MBTA records, a work order was opened on January 3, 2017 and closed on January 27-2017 for railcars 1511 and 1510.

4.3 Postaccident Equipment Examination & Testing

Following the accident, the train was taken out of service and moved to the MBTA maintenance facilities in Boston. The mechanical group examined and tested the train’s functionality.

4.3.1 Passenger Doors Operation

Postaccident examination and testing determined the passenger service doors operated in accordance with MBTA maintenance criteria. The sensitive edges were found to be in good condition with no visible tears or rips and were properly aligned and adjusted. The gap between door leaves was within MBTA maintenance standards.

Obstruction tests determined the doors were operating as designed. With the train at a complete stop, a 7/8-inch dowel obstruction placed between the door leaves would cause the door to recycle until the obstruction was removed. The obstruction tests were performed in 3 locations on the door as specified in the PMI.

The investigation further determined that while the train was moving, if an obstruction was detected by the doors, the door recycle feature would cycle the obstructed door leaf open/close until the train speed reached 3 mph or higher. Once the 3-mph speed threshold was reached, the obstructed leaf would close as much as the obstruction allowed and the door leaf would be held in that position by the pneumatic cylinder that operated the doors.

4.3.2 Automatic door starting signal Button & Door Pilot Lights

Postaccident testing determined the automatic door starting signal button when depressed, would only produce an audible signal when all passenger service doors were completely closed, and no obstructions were detected by the system that would cause the doors to recycle. Testing determined the automatic door starting signal button would not buzz if a passenger service door was open, obstructed or recycling.

The postaccident testing also determined the exterior door pilot lights were properly functioning. The door pilot lights provided a visual cue to train operators that all doors were closed. The door pilot lights remained illuminated during the obstruction tests with the train in motion and stationary.

4.3.3 Train Propulsion with Open Doors

The postaccident investigation found that trainline propulsion was enabled regardless the state of the door interlock relay. This allowed a train operator to place the master controller in propulsion and initiate a train movement regardless of the open/close position of the passenger service doors throughout the train consist. This door operation was contrary to the design of the safety features that prevented any train movement with any service doors open unless the bypass switch was enabled.

Testing of the train consist determined the fault that allowed the train to move with the doors in an open position was located on lead car 1511. Examination of the train door and trainline propulsion circuits found that trainline propulsion was energized with 37 volts and was not affected by any changes to the state of the door interlock relay. Further examination of the Cineston electro-mechanical contact connections (wire terminal board and finger contacts) located under the master controller of the lead car, found that wires protruding out of the crimped terminal of wire B3 were completing an electrical contact with the mounting screw where the B3A wire was connected.

A review of the circuit schematics determined that the unintended electrical connection (short) was bypassing the door interlock relay and therefore provided 37 volts to enable trainline propulsion. (See Figure 3)

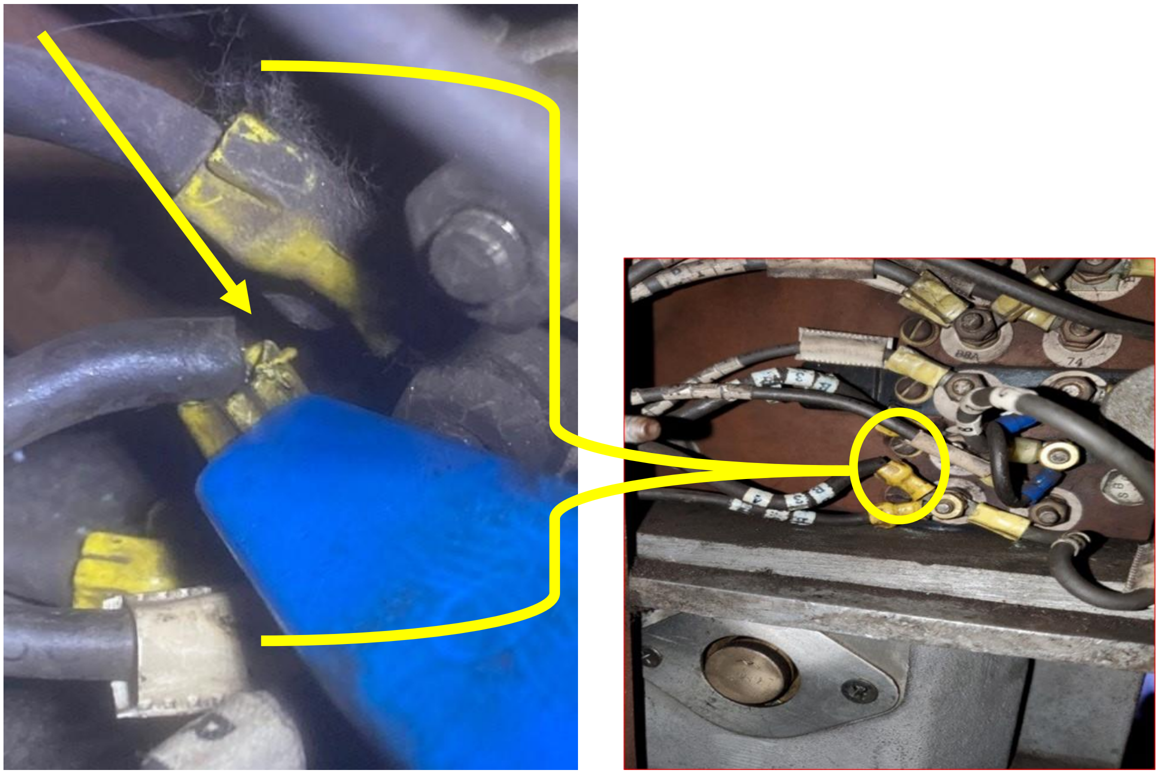

Figure 3. Photos of Electrical Bypass on Propulsion Circuit

A review of the circuit schematics determined the automatic door starting signal button and the exterior door pilot lights were not in the same circuit as the bypass circuit that was identified.

E. POSTACCIDENT ACTIONS

Following the on-scene investigation, the MBTA initiated steps to address the items that identified in the postaccident examination and testing.

- MBTA updated the PMI for door obstruction testing and door interlock testing to include manipulating the master controller handle with the doors open to verify a train will not move under propulsion.
- Using the updated PMI procedures, MBTA cycled the Red Line railcar fleet through the maintenance facility to audit and identify other railcars demonstrating the same issues identified in the investigation. MBTA reported that no other instances were found where a train with open doors could move when propulsion power was applied.
- Implemented a method for electrical isolation between wire terminals and mounting screws on the Cineston terminal block fingers. (See figure4)
- MBTA is expected to retired from service the Red Line #1 Fleet. The retirement of the Red Line Fleet will begin with the 1600 Series Cars

followed by the 1500 Series. The reason for this is due to the fact the 1600 Series only has one Air Compressor per Married Pair and the MBTA's Operational Rules state there can only be one (1) 1600 Series Married Pair in a six (6) Car Consist which is comprised of three (3) Married Pairs.

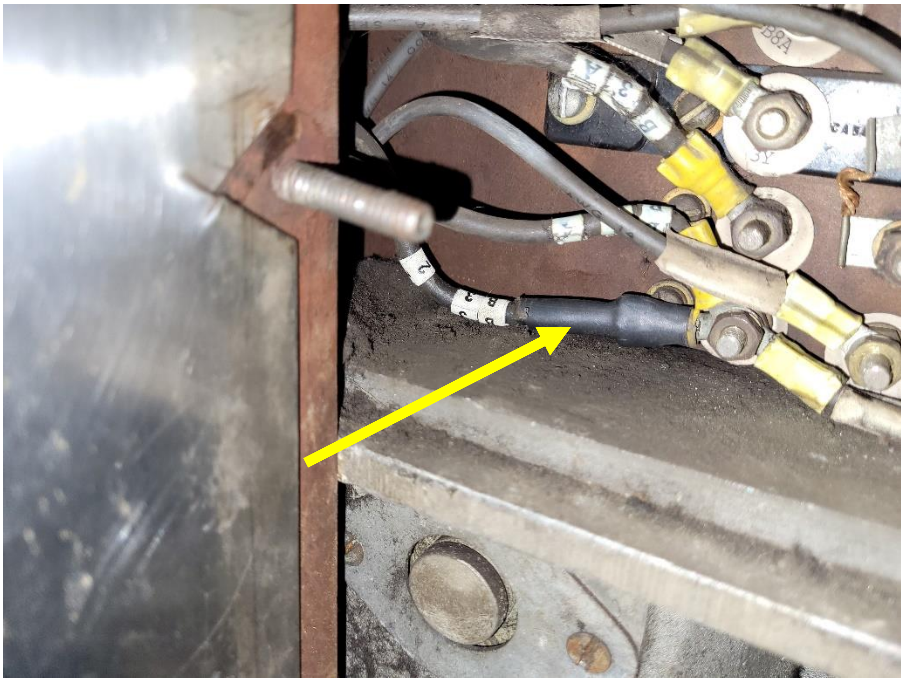

Figure 4. Postaccident Electrical Isolation

END of MECHANICAL FACTUAL REPORT